Laboratory 3: Moon phases & eclipses

Experiments are to be completed on the provided laboratory sheets ONLY; any supporting material (eg. graphs) should be attached. Make sure you and your partner(s) name(s) are clearly indicated on the front page of your lab. **Neatness & clarity count!** Use complete sentences in answering questions, explain your answers clearly & fully, and *write down any equations* before using them in a calculation (i.e. before you insert numbers & solve). **Show all of your work!**

Labs must be written using *non-erasable media* and are due a week after the lab.

**** Do NOT include intro or theory pages in your file submissions for marking. ****

APPARATUS

Starry Night or *SkySafari* or other equivalent planetarium software, two (2) metresticks, one (1) two-metrestick, tape, colour markers/pencils, two different sized circles (see end of lab).

OBJECTIVE

1. To practice working with the phases of the Moon
2. To verify, experimentally and theoretically, when total solar eclipses occur

THEORY

1). An *elliptical* orbit can be characterized by its *semi-major axis*, a and *eccentricity*, e. When e is close to *zero*, the orbit is close to circular; when e is close to *one*, the orbit is *highly* elliptical.

Figure 1 shows the orbit of the Earth about the Sun. The point P, where the Earth is closest to the Sun, is called *perihelion*. The distance between the Earth and Sun may be found from a and e by $r_P = a(1-e)$. The point A, where the Earth is furthest from the Sun, is called *aphelion*. The distance between the Earth and Sun may be found from a and e by $r_A = a(1+e)$.

The above formulae can be used to calculate the minimum and maximum distances for *any* object orbiting another object; however, you must make sure to use the correct a and e for the orbit.

(Example) *For Mars,* $a = 2.28 \times 10^8$ *km and* $e = 0.093$*. As a result, Mars' distance from the Sun would range from* $r_P = a(1-e) = (2.28 \times 10^8)(1-0.093) = 2.07 \times 10^8$ *km (closest) to* $r_A = a(1+e) = (2.28 \times 10^8)(1+0.093) = 2.49 \times 10^8$ *km (furthest).*

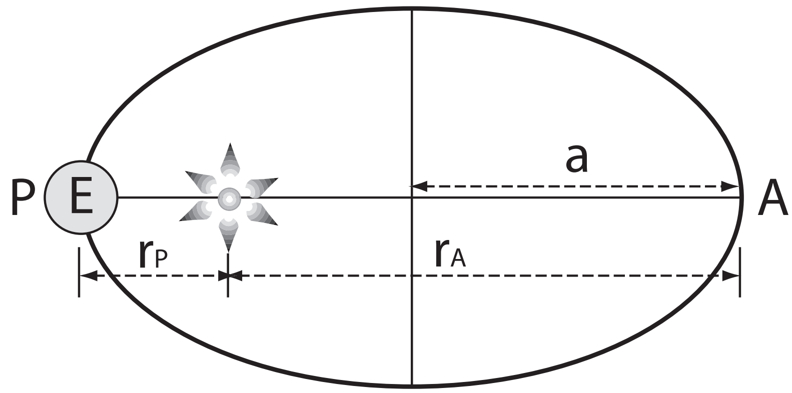

Figure 1: An example of an elliptical orbit.

2). The *angular size* of objects in the sky is also important. How big an object looks depends on how big it is and how far away it is; the relationship between the *diameter* of the object, d_o, the distance to the object, d, and the *angular size* of the object, θ, in degrees is given by

$$\theta = 57.3 \times \frac{d_o}{d}$$

(Example) *The Sun is 149,598,000 km away and has a diameter of 1,392,000 km. The angular size of the Sun in our sky is:*

$$\theta = 57.3 \times \frac{d_o}{d} = 57.3 \times \frac{1,392,000}{149,598,000} = 0.53^\circ$$

3). To compare two experimental values use *percent difference*:

$$\text{Percent Difference} = \frac{(high - low)}{average} \times 100$$

(Example) *We measure two values to be 1.5 and 1.7 units; comparing them,*

$$\text{Percent Difference} = \frac{(high - low)}{average} \times 100 = \frac{(1.7 - 1.5)}{1.6} \times 100 = 12.5\%$$

The two values differ from each other by nearly 13%.

Mark this lab: ☐ individually ☐ as a group NAME: PARTNER:

Laboratory 3: Moon phases & eclipses

Part A: Phases of the Moon

1. Using *Starry Night Enthusiast* (computer lab B315-113) or another *planetarium app* **set the location to Nanaimo and the date/time to Oct 28, 2026 at 9pm PDT**.

2. [***2 marks***] Locate & center the Moon and **record its compass direction and height above the horizon:** ____________________ . Zoom in on the Moon until the field of view is approximately 1°. **What is the phase of the Moon?** ________________ . Zoom out until the field of view is about 100°. Increase the time using the hour and minute controls until the Moon reaches its highest point in the sky. **When does this occur?** ________ **. In class, what time did we predict this phase would be highest?** ______________ **.**

3. [***2 marks***] Based on class discussions, **on what day should the *next* Full Moon occur? Predicted date:** ________________ **. Explain your reasoning below.** Increment the day until the Moon reaches full & **record the actual date:** ________________ .

4. [***2 marks***] **Set the date for Oct 8, 2014 at 1:00 am PDT**. Locate the Moon & center it so that the window tracks with the Moon over time. Zoom in until the field of view is approximately 1°. Advance the time using the minute controls. **Describe the changes to the Moon's appearance STARTING at 1:17am and then at 2:15am. What *specific* type of event is occuring?**

5. [***1 mark***] The photo above taken from Apollo 8 in lunar orbit shows a *gibbous* Earth. If north is "up", **determine the phase of the Moon at this time. EXPLAIN your reasoning fully**.

Part B: Eclipses

1. [***2 marks***] **Calculate** the Earth-Sun distance (in km) during *perihelion* and *aphelion*; the Earth's orbit has a *semi-major axis* of $a = 1.496 \times 10^8$ km and *eccentricity* of $e = 0.017$. Show your work! **From your answers, is Earth's orbit close to or far from being circular? Explain.**

2. [***2 marks***] **Calculate** the *angular size* of the Sun on the sky during *perihelion* and *aphelion* (Sun's diameter is 1.392×10^6 km). This yields a *range* of angular sizes for the Sun as seen from Earth. **Does the Sun's angular size vary significantly? Would you expect it to? Explain.**

3. [***1 mark***] As viewed from Earth, the Moon's range of angular sizes is $0.49° - 0.55°$. **Given this range & that in Q2, is the Moon's orbit more or less elliptical than Earth's? Explain.**

4. [***1 mark***] **Given the ranges of angular sizes for the Sun and for the Moon, why are annular solar eclipses more common than total solar eclipses?** (Set your *planetarium program* for May 20, 2012 at 6:31pm in Reno, Nevada for a nice example of an annular eclipse).

Part C: Eclipse Simulation

1. [***1 mark***] **** There is an online video demonstration for this portion of the lab. **** Form groups of four (4). Get ONE two-metrestick and TWO one-metresticks. Cut out the two circles on the last page of the lab. **Measure** the *diameters* of both circles **(in meters)**:

$d_{large} =$ ____________ m, $d_{small} =$ ____________ m.

2. *Colour the larger circle* (only) with a hi-liter or equivalent and use tape to align the *centre of each circle with the end of a one-metrestick.* Lay the two-meterstick on a table with the 'zero' end **even with one end of the table; this end will serve as the observing position**.

3. Have two group members each hold one of the metresticks with attached circles. The member with the *small* circle should hold their metrestick vertically (circle end up) with the base of the metrestick resting on the horizontal two-metrestick at a distance of **1.00 m** from the table end. The group member with the *large* circle should hold their metrestick vertically (circle end up) with the base of the metrestick resting on the horizontal two-metrestick at a distance of **1.05 m**. A third group member (**the observer**) should position themselves so their eye is **at the same height as the centers of the circles & directly above the 'zero' on the two-meterstick** (i.e. the table end). The observer should view along the direction of the two circles **using only one eye**.

4. [***1 mark***] *Making sure to keep the metresticks vertical & the circles' centers aligned, slowly move the LARGER circle away from the observer* until the observer **FIRST** sees the small circle *completely* cover (eclipse) the large one. **Record the position of the large circle (in meters) FROM the observer in the table below. Repeat so all members view the eclipse and obtain a position. Calculate the *average* position (and hence, distance from observer) of the large circle**. NOTE: the small circle remains at at a position of 1.00 m from the observer.

Position of Large Circle (m)					Average

5. [***5 marks***] **Calculate** the *angular size* (see Lab 1) in degrees of both the large AND the small circle as viewed by the observer at the moment of eclipse; **use the CORRECT diameter & (average) distance for each circle. Compare the circles' angular sizes** using *percent difference.* **Comment.** How *should* their angular sizes compare when (barely) in 'eclipse'? **Explain.**